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ENHANCING EFFICIENCY OF ORGANIC LIGHT EMITTING DIODES THROUGH DOPING OF CADMIUM SULPHIDE NANOCRYSTALS

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ABSTRACT

CdS nanocrystals are synthesized by wet chemical deposition technique without using any capping agent. Next a hybrid optoelectronic structure is presented, where a monolayer of CdS quantum dots is sandwiched between PEDOT: PSS and MEHPPV organic layers. The cells that were doped with CdS quantum dots and undoped ones were compared for performance thereafter. Since CdS has 2.42 eV (515 nm) band gap, so it is most promising candidate among II-VI compounds for detecting visible radiation. As CdS has wide band gap, it is used as window material for hetero junction solar cells and OLEDs to avoid the recombination of photo generated carriers, which improves the cells efficiency. It has also application in photo detectors, Sensors, address decoders and electrically driven lasers.

KEYWORDS: OLEDs, CdS Nanoparticles, Nanocomposites, Doping, Organic Polymers

INTRODUCTION

The major drawback with organic light emitting diode is that the emission spectra of many light-emitting molecules are broad due to vibration and rotational motion of atoms and fall in the range of wavelength between 50 and 100 nm, whereas certain nanocrystals typically yield a sharp emission spectrum covering a range of less than 30 nm. This paves the way to present a hybrid structure, which incorporates light emitting inorganic nanocrystals in conjunction with conductive polymers: quantum dot OLEDs.

The favored design contains three layers: a thin emissive layer sandwiched between a polymeric hole-transport layer (HTL) and an electron-transport layer (ETL). If the emissive layer is thick, electrons and holes must be injected into it and transported; the emissive layer must then replace both the ETL and the HTL, which is not ideal. If instead the emissive layer consists of a single layer of molecules, electrons and holes may be transferred directly from the surfaces of the ETL and the HTL, and high recombination efficiency is expected.

CdS nanocrystals are synthesized by wet chemical deposition technique without using any capping agent. Next a hybrid optoelectronic structure is presented, where a monolayer of CdS quantum dots is sandwiched between PEDOT: PSS and MEHPPV organic layers. The cells that were doped with CdS quantum dots and undoped ones were compared for performance thereafter. Since CdS has 2.42 eV (515 nm) band gap, so it is most promising candidate among II-VI compounds for detecting visible radiation. As CdS has wide band gap, it is used as window material for hetero junction solar cells and OLEDs to avoid the recombination of photo generated carriers, which improves the cells efficiency. It has also application in photo detectors, Sensors, address decoders and electrically driven lasers.

EXPERIMENTAL DETAILS

Preparation of Sample 1

All chemicals were of analytical grade and used as received without further purification. CdS nanoparticles were grown by the chemical precipitation method at room temperature. In synthesis procedure 100 ml aqueous solution of the reactants was prepared. 0.1 M $CdCl_2$ (1.833 gms) and 0.1 M Na_2S (0.78 gms) were used as the reactant materials. Freshly prepared aqueous solution of 0.1M Na_2S was mixed drop by drop in the 0.1 M $CdCl_2$ solution using vigorous stirring. As the reaction was started the reaction system gradually changed from transparent to light yellow and after completion of reaction this turn to dark yellow. The dispersed particles were then washed several times with ethanol and centrifuged. The precipitate collected from centrifugation was dried at 50ºC for few hours. This dried CdS powder was used to characterize Photoluminescence spectra. While, for recording UV-Visible absorption spectrum, CdS powder was dispersed in DMSO and ultasonicate.

Preparation of Sample 2

For preparation of this sample 0.1 M $CdCl_2$ (1.833 gms) and only 30 drops of 0.1 M Na_2S (0.78 gms) were used as the reactant materials. After stirring the mixture for ½ hours by magnetic stirrer, the dispersed particles were washed with ethanol and centrifuged and dried for few hours just like mentioned above.

Characterization

UV-Vis absorption spectra were recorded in the range 200 to 800 nm. Photoluminescence spectra of CdS nanoparticles samples with 400 nm and 430 nm excitation wavelengths were taken for characterization. The photoluminescence emission spectrum of the synthesized CdS nanoparticles is shown in fig at excitation wavelength 400 nm. The spectrum that is obtained by absorption of electromagnetic radiations is called absorption spectra. Figure shows the room temperature UV- Vis absorption spectrum of the CdS nanoparticles. The absorption edge was found at less than 550 nm in prepared samples of CdS, which indicates the blue shift in absorption edge. Sample 2 showed better synthesis of CdS nanoparticles and less agglomeration. A chemical precipitation method has been successfully developed to synthesize CdS nanoparticles without using any capping agent at room temperature.

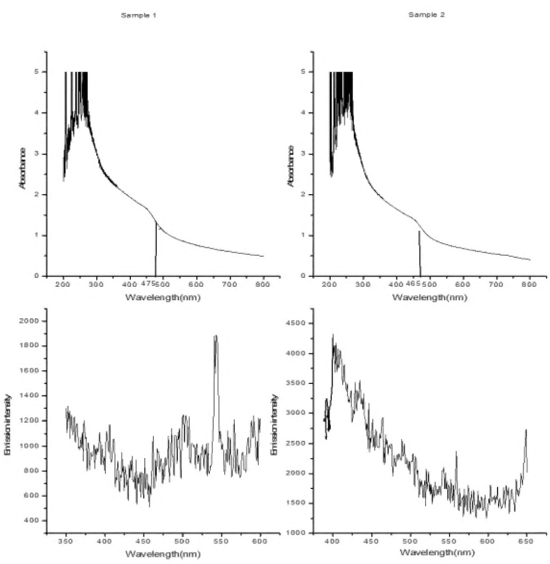

Figure 1

FABRICATION OF DEVICE

Creation of Patterned ITO Substrates (1"Squares)

Pattern

The goal is to pattern individual 1" squares, but for ease of processing, we actually first pattern a 4.25" sheet, and dice it down to 1" squares afterwards. The patterning process that we currently use in the lab is to use plating tape as an etch mask, and to pattern the tape using the dicing saw (limited to 1D patterning). Since this step was not of very interest, and time consuming, this step is described in brief. A thin strip of plating tape is placed on a piece of ITO. This taped over area will be the only non- etched portion, and the rest of the ITO will be stripped away to bare glass.

Etch

The etching itself is a simple one step process. We take the ITO coated glass, protected by plating tape, and dip it into the acid etches. Our etch mixture is 300mL deionized water, 225mL hydrochloric acid (HCl), and 75mL nitric acid (HNO3). The etch time for our ~150nm thick ITO is 15 minutes under vigorous stirring at room temperature. We then rinse off the acid under DI water, and a peel off the plating tape, and measure the resistance of our ITO strip using an ohmmeter.

Dice

To do this we will use a Micro automation Dicing Saw. A thin diamond grit resin blade is used to literally slice through the glass. Precise motor controls allow this machine to have 0.0005" resolution in the vertical direction (half of one mm, 13um), a similar resolution in the glass plane. Most important to us is the z-resolution, since we need to cut entirely through the glass (43mm thick), but only half way through the backing tape (3mm thick) so as not to shatter the fragile blade on the vacuum chuck.

Cleaning

Next we must clean off our 1" squares of patterned ITO, to insure repeatable, low resistance ITO/organic interfaces. This process takes about 2-3 hours, though it is possible to clean as many slides as you may need in that amount of time. The substrates are first cleaned in a water-based detergent for 2 minutes; rinsed with water. It is then washed with acetone and ultra sonicated in DI water for ½ hour; ultra sonicated in Acetone for 15-20 minutes; Washed in boiling trichloroethylene (TCE) and cleaned with vapors of TCE. Finally the substrates are washed with vapors of boiling isopropanol and baked in vacuum oven for 2 hours to dry. This process renders the substrates clean and free from inorganic as well as organic impurities.

PEDOT: PSS Deposition

PEDOT: PSS or Poly (3, 4- ethylenedioxythiophene) poly (styrenesulfonate) is used as a transparent, conductive polymer with high ductility in different applications. If high boiling solvents like dimethyl sulfoxide, sorbitol are added conductivity increases many orders of magnitude which makes it also suitable as a transparent electrode, for example in touch screens, organic light-emitting diodes and electronic paper to replace the traditionally used indium tin oxide. Due to the high conductivity (up to 1000 S/cm are possible), it can be used as a cathode material in capacitors replacing manganese dioxide or liquid electrolytes.

After the filtration of PEDOT: PSS with a 0.25µm syringe filter, a film approximately 80 nm in thickness is obtained on the wafer by spin- coating the solution at 1200 rpm for 1 minute. To increase the conductivity of the PEDOT: PSS film, the sample is baked at 120°C under vacuum oven for 2 hours.

MEH PPV Polymer Deposition

MEHPPV or poly [2-methoxy-5-(2'-ethyl- hexyloxy)-1, 4-phenylenevinylene is used as the emitting layer of OLED structure. Next, 8 mg/ml MEH-PPV/ chlorobenzene solution is ultrasonicate for at least 2 hours until the polymer is fully dissolved. After filtering the mixture with a 0.25 µm Teflon syringe filter, the MEH-PPV solution is spin coated onto the wafer at 1000 rpm. Then, the film is baked at 120°C for 2 hours. This obtains a film thickness of approximately 100 nm.

Metallization of Aluminium Electrode

For the deposition of the aluminum electrodes, a shadow mask is prepared from a 50µm thick copper foil. A vacuum chamber is then used to evaporate a 120 nm aluminum layer. The shadow mask with 3 mm wide holes is aligned perpendicular to the patterned ITO and forms 3X3mm2 square test cells.

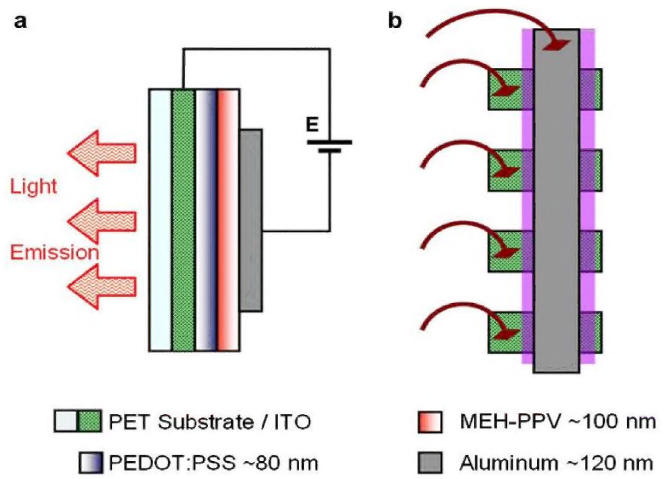

Figure 2

Light absorbing material studied was MEH-PPV. Hole transport material studied was PEDOT: PSS. Electron transport material studied was CdS.

Description of Different OLED Cells Fabricated

Three cells of different deposition layers were fabricated:

- Cell 1(C1) was undoped and fabricated by the above procedure.
- Cell 2(C2) was fabricated by doping 1 mg of sample1 CdS nanoparticles in 8mg/ml MEHPPV/ chlorobenzene mixture and ultrasonicate for 2 hours.
- Cell 3(C3) was fabricated by doping the MEHPPV/chlorobenzene mixture with sample2 and ultrasonicate for 2 hours.

RESULTS AND DISCUSSIONS

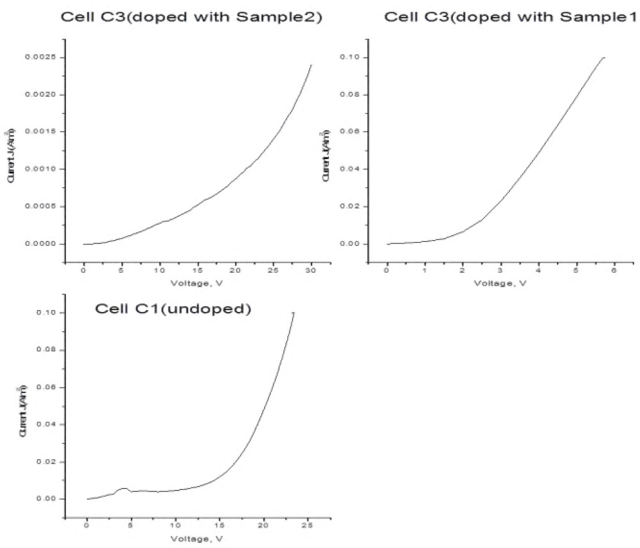

Figure 3

The size-controlled CdS quantum dots are synthesized by using the wet chemical synthetic method. We obtained the optical properties using the absorption and PL spectra of the CdS quantum dots. Sharp peaks in both the UV–Vis absorption and PL spectra indicate that the size distribution of the diameter is nearly monodisperse. It could be applied to the fabrication of OLEDs. The current-voltage characteristics of ITO/MEH-PPV/Al and MEHPPV & CdS doped structures have shown a typical Schottky diode like behavior. Cell C3 doped with sample2 showed better performance compared to the undoped and doped sample1 MEHPPV cells (C1 & C2).

It is confirmed that binary solvent mixtures play an important role in the fabrication of hybrid inorganic semiconductors and conjugated polymer blends, which are used for electronic applications. Therefore, it needs further works to obtain the improved performance of OLED cells.

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